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JC944 U.S. PTO 10/25/00

jc922 U.S. PTO 09/696141 10/25/00

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR § 1.53(b))

Attorney Docket No.	4015-717
First Inventor or Application Identifier	Paul W. Dent
Title	CRYPTOGRAPHIC METHOD AND SYSTEM FOR DDOUBLE ENCRYPTION OF MESSAGES
Express Mail Label No.	EL659735167US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. ☒ *Fee Transmittal Form *(e.g., PTO/SB/17)* *(Submit an original and a duplicate for fee processing)*
2. ☒ Specification [*Total Pages* 33] *(preferred arrangement set forth below)*
   - Descriptive title to the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. ☒ Drawing(s) *(35 U.S.C. 113)* [*Total Sheets* 4]
4. ☒ Oath or Declaration [*Total Pages* 3]
   a. ☒ Newly executed (original or copy)
   b. ☐ Copy from a prior application (37 C.F.R. § 1.63(d)) *(for continuation/divisional with Box 17 completed)* ***[Note Box 5 below]***
      i. ☐ DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference *(useable if Box 4b is checked)* The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Microfiche Computer Program *(Appendix)*
7. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. ☐ Computer Readable Copy
   b. ☐ Paper Copy (identical to computer copy)
   c. ☐ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. ☒ Assignment Papers (cover sheet & document(s))
9. ☐ 37 C.F.R. § 3.73(b) Statement *(when there is an assignee)* ☒ Power of Attorney
10. ☐ English Translation Document *(if applicable)*
11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
14. ☐ *Small Entity Statement(s) ☐ Statement filed in prior application, Status still proper and desired
15. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. ☒ Other: Express Mail Certification

**NOTE FOR ITEMS 1 & 14:* *IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).*

17. If a CONTINUING APPLICATION, *check appropriate box and supply the requisite information below and in a preliminary statement:*
☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No: ______/______
Prior application information: *Examiner:* *Group/Art Unit:*

18. CORRESPONDENCE ADDRESS

☒ *Customer Number or Bar Code Label* 24112 *(Insert Customer No. or Attach bar code label here)* PATENT TRADEMARK OFFICE or ☐ *Correspondence address below*

NAME					
ADDRESS					
CITY		STATE		ZIP CODE	
COUNTRY		TELEPHONE		FAX	

Name (Print/Type)	David E. Bennett	Registration No (Attorney/Agent)	32,194
Signature	David E. Bennett	Date	10/25/00

FEE TRANSMITTAL

Patent fees are subject to annual revision on October 1
These are the fees effective December 29, 1999.
Small Entity payments must be supported by a small entity statement. otherwise large entity fees must be paid. See Forms PTO/SB/09-12. See 37 C.F.R. §§ 1.27 and 1.28.

TOTAL AMOUNT OF PAYMENT | **($)1,512.00**

Complete if Known	
Application Number	TBA
Filing Date	TBA
First Named Inventor	Paul W. Dent
Examiner Name	TBA
Group Art Unit	TBA
Attorney Docket No.	4015-717

METHOD OF PAYMENT (check one)

1. ☒ The Commission is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number: 18-1167

Deposit Account Name: Coats & Bennett, P.L.L C.

☒ Charge Any Additional Fee Required Under 37 CFR §§1.16 and 1.17

☐ Charge the Issue Fee Set in 37 CFR §1.18 at the Mailing of the Notice of Allowance

2. ☒ Payment Enclosed.
☒ Check ☐ Money Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	690	201	345	Utility filing fee	710.00
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	760	208	380	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($)710.00

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims	49	-20** =	29	X	18	=	522
Independent Claims	6	-3** =	3	X	80	=	240
Multiple Dependent Claims				X		=	

*** or number previously paid, if greater, For Reissues, see below*

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	260	204	130	Multiple dependent claim
109	78	209	39	**Reissue independent claims over original patent
110	18	210	9	**Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($)762.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examination action	
115	110	215	55	Extension for reply within first month	
116	380	216	190	Extension for reply within second month	
117	870	217	435	Extension for reply within third month	
118	1,360	218	680	Extension for reply within fourth month	
128	1,850	228	925	Extension for reply within fifth month	
119	300	219	150	Notice of Appeal	
120	300	220	150	Filing a brief in support of an appeal	
121	260	221	130	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,210	241	605	Petition to revive - unintentional	
142	1,210	242	605	Utility issue fee (or reissue)	
143	430	243	215	Design issue fee	
144	580	244	290	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt.	
581	40	581	40	Recording each patent assignment per property (times number of properties)	40.00
146	760	246	380	Filing a submission after final rejection (37 CFR 1.129(a))	
149	760	249	380	For each additional invention to be examined (37 CFR 1.129(b))	

Other fee (specify) ____________

Other fee (specify) ____________

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($)40.00

SUBMITTED BY				Complete (if applicable)	
Typed or Printed Name	**David E. Bennett**			Reg. Number	**32,194**
Signature	David E. Bennett	Date	10-25-00	Deposit Account User ID	18-1167

Express Mail Label No.: EL659735167US
Date Mailed: October 25, 2000

UNITED STATES PATENT APPLICATION FOR GRANT OF LETTERS PATENT

Paul W. Dent
INVENTOR

CRYPTOGRAPHIC METHOD AND SYSTEM FOR DOUBLE ENCRYPTION OF MESSAGES

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CRYPTOGRAPHIC METHOD AND SYSTEM FOR DOUBLE ENCRYPTION OF MESSAGES

BACKGROUND OF THE INVENTION

The present invention relates to cryptographic methods and, more particularly, to a method for signing and encrypting messages using keys with different moduli.

Encryption is the process of disguising intelligible information, called plaintext, to hide its substance from eavesdroppers. Encrypting plaintext produces unintelligible data called ciphertext. Decryption is the process of converting ciphertext back to its original plaintext. Using encryption and decryption, two parties can send messages over an insecure channel without revealing the substance of the message to eavesdroppers.

A cryptographic algorithm or cipher is a mathematical function used in the encryption and decryption of data. Many cryptographic algorithms work in combination with a key to encrypt and decrypt messages. The key, typically a large random number, controls the encryption of data by the cryptographic algorithm. The same plaintext encrypts to different ciphertext with different keys. In general, it is extremely difficult to recover the plaintext of a message without access to the key, even by an eavesdropper having full knowledge of the cryptographic algorithm.

One type of cryptographic algorithm, known as public key algorithms, use different keys for encryption and decryption. An encryption key, also called the public key, is used for encrypting data and is accessible to other users. Anyone can

use the public key to encrypt messages. A decryption key, also called the private key, is kept secret and is used to decrypt messages. Only a person with the private key can decrypt messages encrypted with the corresponding public key. During use, the sender encrypts a message using the public key of the intended recipient. Only the intended recipient can decipher the message using his private key. Since the private key is not distributed, public key algorithms avoid the problems of key exchange inherent in symmetric algorithms.

One of the most popular public key algorithms is the RSA algorithm, named after its three inventors -- Ron Rivest, Adi Shamir, and Leonard Adleman. The RSA algorithm takes a message M and encrypts it using the formula $C = M^E \bmod N$, where N is the product of two large prime numbers P, Q chosen at random. The exponent E is a number relatively prime to $(P-1)(Q-1)$. The encrypted message C is deciphered using the formula $M = C^D \bmod N$ where $D = E^{-1} \bmod ((p-1)(q-1))$. The exponent E and modulus N are used as the public key. The exponent D is the private key. The primes P and Q are not needed once the public and private keys have been computed but should remain secret.

The RSA algorithm, and other public key algorithms, allow secure communications between two parties, but do not provide a means for authenticating the parties. When a person receives a message encrypted with his public key, he can be assured that the content of the encrypted message is secret, since only he possesses the key for decrypting the message. However, the party receiving the encrypted message has no assurance of the identity of the sending party, since anyone with his public key could have encrypted the message.

If the receiving party desires to authenticate the sending party's identity, the sending party may sign the message by encrypting it with his private key. The receiving party can then use the sender's public key to decrypt the message. If the message is decrypted successfully, only the sending party in possession of the private key could have sent that message. This process of authenticating the message by encryption using the sender's private key is referred to as signing.

It is known to doubly encrypt messages to provide both secure communications and authentication capability. In this case, each party to the communication possesses a public key used for encrypting messages and a private key used for decrypting messages. Assume that party A wishes to send party B a message. Party A encrypts the message first, using party A's private key. The resulting ciphertext is encrypted a second time, using party B's public key. The result of these second encryption operations is transmitted to party B. Party B decrypts the message using party B's private key. Since party B is the only person in possession of the private key, only he can decrypt the message, so the communication is secure. The result of the first decryption operation is the inner ciphertext produced by encrypting the original message with party A's private key. Thus, party B can then use party A's public key to decrypt the inner ciphertext to obtain the original message. Since only party A possesses the private key that can generate the inner ciphertext, party A's identity is authenticated to party B.

When using the RSA algorithm for encryption, the message M is broken into blocks such that the length of each message block is less than the encryption modulus. The reason for breaking the message into blocks having a length less

than the encryption modulus is to avoid loss of data. A similar procedure is typically used when a message is to be signed using the sender's private key and then encrypted using the recipient's public key. In this case, the message M is partitioned into blocks of a fixed length one or more bits less than the binary length of a first encryption modulus, which is used in the signing operation. The output of the signing operation is a sequence of blocks equal to the length of the first encryption modulus. The blocks output during the signing operation are recombined and repartitioned to form input blocks of a fixed length one or more bits less than the length of a second encryption modulus associated with the receipient's public key. The resulting message blocks are then encrypted using the recipient's public key. This procedure avoids loss of data by ensuring that the numerical value of each message block is less than the encryption modulus used during the signing or encryption operations.

BRIEF SUMMARY OF THE INVENTION

The present invention is directed to a method of signing and encrypting messages using encryption keys having different moduli. A message is created by appending an error detection code to an information block. The binary value of the resulting message is then compared to the sender's encryption modulus. If the binary value of the message is greater than or equal to the sender's encryption modulus, at least one bit of the error detection code is altered to reduce the binary value of the message below the sender's encryption modulus. The potentially modified message is then encrypted once using the sender's private key to

generate a once encrypted bitstring referred to herein as the signed message. The signed message is then encrypted a second time using the recipient's public key to produce a doubly encrypted bitstring referred to herein as the encrypted message.

The recipient deciphers the encrypted message, i.e., doubly encrypted bitstring, using the recipient's private key to recover the signed message, i.e., once encrypted bitstring. The signed message comprises the original plaintext message encrypted to the sender's private key. The signed message is then deciphered using the sender's public key to obtain an estimate of the original plaintext of the message.

Following decryption, a validity check is performed by first decoding the estimate of the message in a decoder. If decoding is successful, the estimate is accepted as valid. If decoding produces an error, it is possible that the error is due to a change in a bit of the error detection code by the sender. Therefore, a bit alteration check is performed to determine whether change of a predetermined and presumably altered bit to its presumed original value produces a valid message. If so, the restored message is accepted as valid.

If the first estimate cannot be validated, a second estimate of the original plaintext message is generated and the process validation process is repeated. The second estimate is generated by adding the recipient's modulus to the once encrypted message and deciphering the modified once encrypted message to obtain a new estimate of the plaintext message. This process continues until a valid message is produced or until a predetermined number of failed attempts to produce a valid message have been made.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of a cryptographic communication system comprising two cryptographic communication devices used in the present invention for engaging in secure communications over a communications channel;

Figure 2 is a schematic diagram of a cryptographic communication device used in the present invention;

Figure 3 is a flowchart diagram illustrating the steps of encrypting a message in accordance with one embodiment of the present invention;

Figure 4 is a flowchart diagram illustrating the steps of decrypting the message in accordance with one embodiment of the present invention; and

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates a schematic diagram of a cryptographic communication system 10 for transmitting and receiving encrypted messages over an insecure channel. The cryptographic communication system 10 includes two or more communication devices 12 for communicating over an insecure channel 14. Although only two communication devices 12 are illustrated, the communication system 10 may in fact comprise numerous communication devices 12.

The term "communication device" used herein refers to any device capable of transmitting and/or receiving information over a communication channel 14. The communication channel 14 may be a wireline channel or a wireless channel. Communication devices may include: a cellular radiotelephone; a Personal

Communications System (PCS) terminal that may combine a cellular radiotelephone with data processing, facsimile and data communications capabilities; a Personal Digital Assistant (PDA) that can include a radiotelephone, pager, Internet/intranet access, Web browser, organizer, calendar and/or a global positioning system (GPS) receiver. The term communication device also encompasses computing devices, such as a personal computer, laptop computer, or palmtop computer, that includes a communications interface for communicating with other devices. Communication interfaces used in computing devices 12 may for example comprise an Ethernet interface, serial interface, modem, radiotelephone transceiver, or any other interface typically used in a computer to communicate with other devices.

Each communication device 12 includes a communications interface 16, processor 18, and a cryptographic device 20. Processor 18 controls the operation of the communication device 12 and may include either internal or external memory for storing control programs and data used during operation. Processor 18 may further perform some computational functions during the encryption and decryption steps of the communication. Processor 18, however, may not be a secure device such that data stored therein may be accessed by outside parties.

Cryptographic device 20 is typically a secure, tamper-proof device that includes a processor and memory used for cryptographic calculations, e.g. encryption and decryption. Cryptographic device 20 may for example comprise a "smart card" or tamper-proof chip. Data computed and stored within the cryptographic device 20 cannot be accessed by an outside source thus providing

security for the ciphering process. The cryptographic device 20 stores encryption variables, such as public and private keys, used in ciphering algorithms to encrypt and decrypt data. The encryption variables may be generated internally in the cryptographic device 20 to prevent the possibility of tampering or disclosure. While shown in Figure 1 as a separate device, the function of the cryptographic device 20 may in fact be incorporated into processor 18.

Communication interface 16 provides a means for interfacing the communications device 12 with the communications channel 14. Interface 16 may have a variety of embodiments, including a radio frequency transceiver, Ethernet interface, modem, etc.

Figure 2 is a more detailed block diagram of a cryptographic device 20. Cryptographic device 20 comprises microprocessor 22, read-only memory 24, erasable programmable read-only (EPROM) 26, random access memory (RAM) 28, input/output (I/O) interface 30, optional co-processor 32, and encoder/decoder 34. The microprocessor 22 executes programs stored in read-only memory 24 and responds to digital codes presented to the microprocessor 22 on I/O interface 30. The digital codes presented to the microprocessor 22 represent commands to be executed by the microprocessor 22. There are only a limited set of valid commands that may be executed by the microprocessor 22. Valid commands include, for example, requests to encipher or decipher data presented on the I/O interface 30 and to return the result as output bits on the I/O interface 30. Encryption and decryption may be performed using internally stored or externally supplied keys. When encryption is performed using a stored, long-term secret key, such as the

private key of a public/private key pair, it is generally desirable that the encryption operation be performed internally by the microprocessor 22 and one or more co-processors in order to obviate the need for the secret key to be output to an external or off-chip device. In that case, there will be no legal command to request output of the private key to which the microprocessor 22 will respond. Thus, there may be, if necessary, a co-processor 32 to accelerate computations of the sort necessary using public key encryption methods based on very large prime numbers.

Read-only memory 24 stores programs that are executed by microprocessor 22 and its co-processors, if present. The programs stored in read-only memory 24 determine the legal commands. Read-only memory 24 is, typically, factory programmed. The programs stored therein are unalterable to prevent tampering.

EPROM 26 stores user-specific data or other data that must be field programmed. This includes the user's identity certificate and public-key/private-key pair and the associated modulus. The public key may be a relatively small, comprising one to eight decimal digits. The public key is typically published in a catalog or database along with the encryption modulus and user's identity. The encryption modulus is typically a large number in the order of 2048 bits (256 bytes) in length and the private key is of the same order of word length. The public key, encryption modulus, and private key are initially stored in EPROM 26 but, during initialization, the public key and encryption modulus are erased from memory.

The private key may be modified during the initialization process to eliminate random digits corresponding to a user's PIN code. The modified private key, for example, may have some missing digits which have to be filled in by the user to

complete the private key. For example, two bytes of the private key could be left blank and the missing 16 bits grouped to form a 4-digit, hexadecimal PIN code, e.g., 5C1F. A related U.S. Patent Application entitled "Secure Storage of Ciphering Information Using a PIN Code," which is being filed concurrently with this application, describes a method for storing encryption data in a tamper-proof chip or "smart card." This application is incorporated herein in its entirety by reference.

Encoder/decoder 34 performs error encoding and decoding. Error encoding allows bit errors that occur during transmission to be detected by the recipient. An information sequence to be transmitted is encoded, for example, by computing a cyclic redundancy check (CRC) code, which is appended to the information sequence. At the receiving end, the CRC is computed on the received information bits and compared to the received CRC bits to determine the number and location of bit errors. Encoder/decoder 34 and bit alteration detector 36 are described in detail below.

The present invention comprises a cryptographic method implemented by a cryptographic communication device 12 for encrypting and decrypting transmitted information. The cryptographic method employs public key encryption and decryption techniques to encrypt and decrypt transmitted information to protect the transmitted information from disclosure. There are numerous public key algorithms suitable for use with the present invention. One such public key algorithm is known as the RSA algorithm, which is used herein to describe an exemplary embodiment of the invention. The RSA algorithm is described in U.S. Patent No. 4,405,829, which is incorporated herein by reference.

The RSA algorithm and other public key algorithms use a first key, called the public key, for encryption operations and a corresponding second key, called the private key, for decryption operations. A message encrypted with the public key can be decrypted only with the private key. Therefore, to engage in secure communications, the sender encrypts the message using the recipient's public key so that only the intended recipient can decipher the message using the corresponding private key.

Another useful property of the RSA algorithm, and other public key algorithms, is that a message encrypted with a private key can also be decrypted with the corresponding public key. Thus, it is possible for a sender to "sign" a message prior to transmission by encrypting the message with his own private key. The recipient can authenticate or verify the "signature" by deciphering the message with the sender's public key. If the message is successfully deciphered with the sender's public key, the sender's "signature" on the message is authenticated. For purposes of this application, encryption with a private key is referred to as signing. The resulting ciphertext is referred to as a "signature."

According to the present invention, both the sender and receiver have a public/private key pair used for encrypted communications. The sender's key pair is denoted (K_{PRIVA}, K_{PUBA}). The recipient's key pair is denoted (K_{PRIVB}, K_{PUBB}). The sender's key pair (K_{PRIVA}, K_{PUBA}) is based on a first encryption modulus denoted N_A while the recipient's key pair (K_{PRIVB}, K_{PUBB}) is based on a second encryption modulus denoted N_B. To avoid the common modulus attack and other known security weaknesses, the sender's encryption modulus N_A and the recipient's

encryption modulus N_B are assumed to be different. In one embodiment, the sender's modulus N_A and the recipient's encryption modulus N_B are the same length, and both have a "1" in the most significant and least significant bit positions. These conditions ensure that the modulus N_A cannot exceed the modulus N_B by a factor of two or more. A message M is signed first using the sender's private key K_{PRIVA} and then encrypted using the recipient's public key K_{PUBB}. The resulting doubly encrypted message is then transmitted to the recipient.

In the exemplary embodiment, the message M comprises an information block and one or more redundant bits. The information block may comprise one or more information bits embodying the substance of the message. The redundant bits may for example comprise error detection bits generated by error detection coding the information block. In the case where the redundant bits are error detection bits, the recipient can use the error detection bits to detect bit errors occurring during transmission. The redundant bits and information bits are referred to collectively as message bits.

The total number of message bits is, in the exemplary embodiment, equal to the number of bits in sender's encryption modulus N_A. Choosing the message length to be equal to the word length of modulus N_A reduces the number of information blocks that must be encrypted. There is, however, a possibility that the numerical value of the message M may equal or exceed the sender's encryption modulus N_A. This possibility is avoided in the present invention by altering at least one message bit in a deterministic manner, known to the recipient, prior to encryption to reduce the numerical value of the message M when the numerical

value of the message M equals or exceeds the sender's encryption modulus N_A. A validity check is performed during decryption to detect and correct any bit changes made by the sender.

Figure 3 illustrates the cryptographic communication method of the present invention. The sender generates or receives an information sequence (block 100), which the sender desires to send to the recipient. The information sequence is assumed to be in digital form and may comprise any alphanumeric, audio, or graphic presentation of any length. The sender partitions the information sequence into one or more information blocks (block 102). Each information block is transmitted separately to the recipient in the following manner. First, the sender performs error detection coding on the information block to generate one or more error detection bits and appends the error detection bits to the information block at step 104 to create a message M. The error detection bits are used by the recipient to verify that the message M has been correctly deciphered. The error detection code may, for example, comprise a cyclic redundancy check (CRC), in which case the error detection bits are the resulting CRC bits. In the exemplary embodiment, the error detection bits are inserted into the information block with one error detection bit occupying the most significant bit (MSB) position in the message M. The error detection bits may simply be appended to the end of the information block such that the error detection bits are contiguous and occupy the most significant bit positions. Alternately, the error detection bits can be interleaved with the information bits in the information block.

Prior to encrypting the message M, a check is made to determine whether the numerical or binary value of the message M is equal to or greater than the sender's modulus N_A (block 106). If the numerical value of message M is equal to orgreater than the sender's encryption modulus N_A, the message M would be reduced during the encryption operation by subtraction of the modulus N_A resulting in data loss. Therefore, when message M is greater than the sender's modulus N_A, the bit occupying the MSB position is changed to 0 (block 110). This ensures that modulus N_A has a greater numerical value and that data will not be lost during the encryption operation. The possibly modified message M is then signed using the sender's private key K_{PRIVA} and encryption modulus N_A (block 112) to create a once encrypted bitstring. If the RSA algorithm is used, encryption is performed using the equation $Y = M^{Kpriva} \bmod N_A$, where Y is the signed message. The signed message Y is encrypted at step 114 using the recipient's public key K_{PUBB} and encryption modulus N_B to create a doubly-encrypted bitstring. Again, if the RSA algorithm is used, the encryption operation is performed using the $Z = Y^{Kpubb} \bmod N_B$ where Z is the encrypted message. The encrypted message Z is then transmitted by the sender to the recipient (block 116).

Figure 4 illustrates the steps involved with deciphering the encrypted message Z to recover the message M. Initially, the encrypted message Z is deciphered using the recipient's private key K_{PRIVB} to obtain an estimate $\hat{Y}$ of the signed message Y (block 200). Mathematically, this is obtained through the formula $\hat{Y} = Z^{PRIVB} \bmod N_B$. A counter C is then initialized to be the integer value of N_A/N_B (block 201), which is necessary to track the number of decoding failures as will be

explained below. C will be zero if $N_A<N_B$. C will be unity if $N_A>N_B$ but N_A and N_B are of the same length. Next, the recipient deciphers the estimate $\hat{Y}$ of the signed message Y using the sender's public key K_{PUBA} to obtain a first estimate $\hat{M}$ of the original message M (block 202). This estimate is obtained through the formula $\hat{M} = Y^{PUBA} \bmod N_A$.

Once the first estimate of message $\hat{M}$ is obtained, the recipient error decodes the first estimate $\hat{M}$ by encoder/decoder 34 to determine if any bit errors occurred during transmission (block 204). Encoder/decoder 34 initially decodes the estimate $\hat{M}$ to detect any bit errors. Error decoding may comprise, for example, performing a CRC check. If the estimate $\hat{M}$ decodes properly (block 206), the estimate $\hat{M}$ is assumed to be the correct value of M (block 210). If error decoding fails, i.e. an invalid CRC is produced, a bit alteration check is performed by the bit alteration detector 36. It is possible that the decoding failure is due to the alteration by the sender of the MSB to reduce the numerical value of the message M below the value of modulus N_A. Since the alteration by the sender occurs in a deterministic manner, encoder/decoder 34 attempts to restore the presumably altered bit to its presumed original value to generate a modified estimate $\overline{M}$ of the original message M. The purpose of the bit alteration detector 36 is to determine whether the modified estimate $\overline{M}$ is valid.

The modified estimate $\overline{M}$ of the message M is accepted if three conditions are satisfied: (1) M contains a single bit error at a predetermined bit location; (2) the value of the altered bit in the predetermined bit location has an expected value, i.e., it is consistent with the error detection code being indicative of no errors; and (3) the

numerical value of a modified estimate $\overline{M}$ of message M is equal to or greater than the modulus N_A. These conditions are tested during a bit alteration check by bit alteration detector 36 in block 212. In the exemplary embodiment, the only permitted bit change is the most significant bit (MSB), but this limitation is not required. Therefore, the bit alteration detector 36 determines whether this bit is in error and whether any other bit errors occurred. If the MSB is correct, or if more than one bit error occurred, an error signal is generated by encoder/decoder 34 (block 214). Assuming that the first condition is met, encoder/decoder 34 determines if the bit in the MSB position is "0." The MSB may have been altered by the sender prior to encryption to ensure that value of the message M is less than the sender's modulus N_A (see block 106 in Figure 3). If the MSB is a "1", then encoder/decoder 34 generates an error signal (block 214), since the error is not due to an intentional bit change which would always comprise a change from a 1 to a 0. Finally, if the first two conditions are met, encoder/decoder 34 changes the MSB from "0" to "1" and the value of the modified estimate $\overline{M}$ is compared to the sender's modulus N_A. If the modified estimate $\overline{M}$ is greater than or equal to N_A, it is determined that the message M was modified during enciphering and the modified estimate $\overline{M}$ with the MSB restored to its presumed original value is a reproduction of the original message M (block 210). However, if a decoding failure occurs, an error signal is generated (block 214). In this case, additional steps are required.

Another potential cause of a decoding failure occurs when the sender's modulus N_A is greater than the recipient's modulus N_B. During the signing step (block 112 in Figure 3), the value of the original signed message Y is in the range of

0 to N_A-1. Thus, when N_A>N_B, it is possible for the numerical value of the signed message Y to exceed N_B-1. In this case, the signed message Y would be reduced to a value less than N_B during encryption by subtraction of modulus N_B. In the practice of the present invention, it is accepted that the value of the signed message Y may be reduced by subtraction of the recipient's modulus N_B or an integer multiple of the recipient's modulus N_B. To account for this occurrence, the value of the estimate $\hat{Y}$ of the signed message Y is increased by the recipient's modulus N_B (block 220) when there is a decoding failure. Before incrementing the estimate $\hat{Y}$ of the signed message, the count C is compared to a predetermined value, which in this case is 0. The count C was initialized to a the integer value of N_A/N_B, which represents the maximum number of times that the signed message Y could have been reduced. Each time the value of the estimate $\hat{Y}$ of the signed message Y is incremented, the loop count is decreased by one (block 220). The second deciphering step (block 202) is repeated to obtain a new estimate $\hat{M}$ of the message M, which is then decoded by encoder/decoder 34 (block 204) to determine the presence of bit errors. If so, a bit error check is performed (block 212) to determine whether the original message M was changed by the sender. This process is repeated until the counter reaches 0 or until a valid estimate M is obtained.

In one embodiment, N_A and N_B have different values, but are of the same binary length, e.g. 2048 bits. Additionally, both moduli N_A and N_B are odd, meaning both have a binary value of "1" in the MSB and a least significant bit (hereinafter LSB) position. This implies that N_A/N_B is less than two. Thus, when the signed

message Y is greater than N_B-1 at most only one N_B is subtracted. In this case, the maximum number of times that the signed message Y can be incremented is 1 and the deciphering step 202 is repeated only once. In general, the maximum number of times Y may be incremented is equal to the integer value N_A/N_B, which is used to initialize the counter.

The present invention may be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

CLAIMS

What is claimed is:

1. A method for enciphering an information sequence for subsequent transmission comprising:

creating an original message by adding one or more bits to said information sequence;

comparing a numerical value of said original message to a predetermined value;

if the numerical value of said original message is equal to or greater than said predetermined value, changing at least one bit in said original message to obtain a modified message having a numerical value less than said predetermined value; and

encrypting said modified message with a key associated with a first modulus.

2. The method of claim 1 wherein creating an original message by adding one or more bits to said information sequence comprises adding a redundant bit to said information sequence at a most significant bit position.

3. The method of claim 2 wherein changing at least one bit in said original message to obtain a modified message having a numerical value less than said predetermined value comprises changing said redundant bit at said most significant bit position.

4. The method of claim 1 wherein comparing a numerical value of said original message to a predetermined value comprises comparing said numerical value of said original message to said first modulus.

5. The method of claim 4 wherein changing at least one redundant bit in said original message to obtain a modified message having a numerical value less than said predetermined value comprises changing at least one bit in said original message such that the numerical value of said modified message is less than said first modulus.

6. The method of claim 1 wherein creating an original message by adding one or more bits to said information sequence comprises adding one or more error detection bits to said information sequence.

7. The method of claim 6 wherein adding one or more error detection bits to said information sequence comprises computing a cyclic redundancy check code and appending said cyclic redundancy check code to said information sequence.

8. The method of claim 1 wherein encrypting said modified message with a key associated with a first modulus comprises encrypting said modified message with a private key based on said first modulus to obtain a signed modified message.

9. The method of claim 8 further comprising encrypting said signed modified message with a key associated with a second modulus less than said first modulus to obtain an encrypted modified message.

10. The method of claim 9 further comprising deciphering said encrypted modified message to obtain a first estimate of said modified message.

11. The method of claim 10 further comprising validating said first estimate of said modified message.

12. The method of claim 11 wherein validating said first estimate of said modified message comprises:

error decoding said first estimate of said modified message using said error detection bits to generate an error indication;

if said error indication indicates no error, accepting said first estimate of said modified message as a reproduction of said original message;

if said error indication indicates an error, altering at least one predetermined bit in said first estimate of said modified message to obtain a modified estimate of said modified message; and

validating said modified estimate of said modified message.

13. The method of claim 12 wherein validating said modified estimate of said modified message comprises performing a bit alteration check to determine whether a predetermined bit of said modified message is an altered bit.

14. The method of claim 13 wherein performing a bit alteration check to determine whether a predetermined bit of said modified message is an altered bit comprises:

determining whether bit errors occurred in said at least one predetermined bit;

if bit errors occurred in said at least one predetermined bit, determining whether the value of said at least one predetermined bit has an expected value; and

if said at least one predetermined bit has an expected value, determining whether said modified estimate of said modified message has an expected value.

15. The method of claim 14 wherein determining whether bit errors occurred in said at least one predetermined bit comprises determining whether a bit error occurred in a most significant bit.

16. The method of claim 15 wherein determining whether the value of said at least one predetermined bit has an expected value comprises determining whether said most significant bit is equal to zero.

17. The method of claim 16 wherein determining whether said modified estimate of said modified message has an expected value comprises determining whether said modified estimate with said most significant bit position equal to one is greater than or equal to said encryption modulus.

18. A method of encrypting a message comprising the steps of:

forming an original message by appending one or more redundant bits to an information sequence;

comparing a value of said original message with a value of a first modulus and modifying said original message to obtain a modified message if said original message is greater than or equal to said first modulus;

signing said modified message with a first key based on said first modulus to form a signed message;

encrypting said signed message with a second key based on a second modulus to form a doubly encrypted message; and

sending said doubly encrypted message to a recipient.

19. The method of claim 18 wherein forming an original message by appending one or more redundant bits to an information sequence comprises forming a message having a length equal to said first modulus.

20. The method of claim 18 wherein signing said modified message with a first key based on said first modulus to form a signed message comprises signing said modified message with a sender's private key.

21. The method of claim 18 wherein modifying said original message to obtain a modified message if said original message is greater than or equal to said modulus comprises changing the value of one of said redundant bits.

22. The method of claim 18 wherein forming an original message by appending one or more redundant bits to an information sequence comprises adding error detection bits computed on said information sequence to said information sequence.

23. A method of deciphering a doubly encrypted bitstring comprising:

deciphering said doubly encrypted bitstring to obtain a once encrypted bitstring;

deciphering said once encrypted bitstring to obtain a first estimate of a plaintext message having one or more error detection bits;

decoding said first estimate of said plaintext message to produce an error indication;

if said error indication indicates an error, performing a bit alteration check to determine whether a predetermined bit in said first estimate of said plaintext message was altered.

24. The method of claim 23 wherein performing a bit alteration check to determine whether a predetermined bit in said first estimate of said plaintext message was altered comprises altering a predetermined bit in said first estimate of said plaintext message to generate a modified plaintext message and testing the validity of said modified plaintext message.

25. The method of claim 23 wherein performing a bit alteration check to determine whether a predetermined bit in said first estimate of said plaintext message was altered comprises checking said first estimate of said plaintext message for a bit error in a predetermined bit position.

26. The method of claim 25 wherein performing a bit alteration check to determine whether a predetermined bit in said first estimate of said plaintext message was altered further comprises determining a value of a bit in said predetermined bit position.

27. The method of claim 26 wherein performing a bit alteration check to determine whether a predetermined bit in said first estimate of said plaintext message was altered further comprises altering said value of said bit in said predetermined bit position to obtain a modified estimate of said plaintext message and comparing a value of said modified estimate of said plaintext message to a predetermined value.

28. The method of claim 23 further comprising:

modifying said once encrypted bitstring if said bit error check produces an error;

deciphering said modified once encrypted bitstring to obtain a second estimate of said plaintext message;

decoding said second estimate of said plaintext message to produce an error indication;

if said error indication indicates an error, performing a bit alteration check to determine whether a predetermined bit in said second estimate of said plaintext message was altered.

29. The method of claim 28 wherein modifying said once encrypted bitstring if said bit error check produces an error comprises adding a predetermined value to said once encrypted bitstring.

30. The method of claim 29 wherein adding a predetermined value to said once encrypted bitstring comprises adding a value equal to a modulus associated with an encryption key used to generate said doubly encrypted bitstring.

31. A method of deciphering a doubly encrypted bitstring comprising:

deciphering said doubly encrypted bitstring to obtain a once encrypted bitstring;

modifying said once encrypted bitstring by adding an integer multiple of a modulus associated with an encryption key used to generate said doubly encrypted bitstring to said once encrypted bitstring to obtain a modified once-encrypted bitstring;

deciphering said modified once encrypted bitstring to obtain an estimate of said plaintext message.

32. The method of claim 31 further comprising decoding said estimate of said plaintext message to produce an error indication.

33. The method of claim 32 further comprising performing a bit alteration check to determine whether a predetermined bit in said estimate of said plaintext message is an altered bit, if said error indication indicates an error.

34. An encryption device comprising:

an error encoder to produce an encoded message having one or more error detection bits, wherein said error encoder alters a predetermined bit in said encoded message to produce a modified message when a value of said encoded message is greater than or equal to a predetermined value; and

a cryptographic processor to encrypt said modified message to obtain an encrypted message.

35. The encryption device of claim 34 wherein said cryptographic processor encrypts said modified message using a first encryption key associated with a first modulus.

36. The encryption device of claim 35 wherein said first encryption key is a private key of a sender of said message.

37. The encryption device of claim 35 wherein said cryptographic processor further encrypts said modified message using a second encryption key associated with a second modulus, wherein said second modulus is different from said first modulus.

38. The encryption device of claim 37 wherein said second encryption key is a public key of a recipient of said message.

39. The encryption device of claim 35 wherein said first predetermined value is equal to said first modulus less one.

40. The encryption device of claim 35 wherein said encoder outputs said encoded message unmodified when said value of said encoded message is less than said predetermined value.

41. The encryption device of claim 35 further comprising a transmitter for sending said encrypted message to a recipient.

42. A device for decrypting data comprising:

a cryptographic processor to decipher a doubly encrypted bitstring to obtain a first estimate of a plaintext message, wherein said cryptographic processor uses a first key associated with a first modulus for a first decryption operation and a second key associated with a second modulus for a second decryption operation; and

a decoder to decode said first estimate of said plaintext message and to generate an error indication, said decoder comprising a bit alteration detector to determine whether a predetermined bit in said first estimate of said plaintext was altered.

43. The device of claim 42 wherein said bit alteration detector alters a predetermined bit in said first estimate of said plaintext message to generate a modified plaintext message and tests the validity of said modified plaintext message.

44. The device of claim 42 wherein said bit alteration detector checks said first estimate of said plaintext message for a bit error in a predetermined bit position.

45. The device of claim 44 wherein said bit alteration detector determines a value of a bit in said predetermined bit position.

46. The device of claim 45 wherein said bit alteration detector alters the value of said bit in said predetermined bit position to obtain a first modified estimate of said plaintext message and compares a value of said first modified estimate of said plaintext message to a predetermined value.

47. The device of claim 42 wherein said cryptographic processor modifies said once encrypted bitstring in response to an error indication from said bit alteration detector to obtain a modified once encrypted bitstring and decodes said modified once encrypted bitstring to obtain a second estimate of said plaintext message.

48. The device of claim 47 wherein said decoder decodes said second estimate of said plaintext message and generates an error indication.

49. The device of claim 48 wherein said bit alteration detector determines whether a predetermined bit in said second estimate of said plaintext was altered.

ABSTRACT OF THE DISCLOSURE

A method and system for encrypting and decrypting a message. A message is created by appending an error detection code to an information block. The binary value of the resulting message is then compared to the sender's encryption modulus. If the binary value of the message is greater than or equal to the sender's encryption modulus, at least one bit of the error detection code is altered to reduce the binary value of the message below the sender's encryption modulus. The potentially modified message is then encrypted once using the sender's private key to generate a once encrypted message referred to herein as the signed message. The signed message is then encrypted using the recipient's public key to produce a doubly encrypted bitstring. The recipient deciphers and decodes the doubly encrypted bitstring. If an decoding failure occurs, the recipient assumes that the error is due to an intentional bit change by the sender and attempts to restore the presumably altered bit or bits to their presumed original value.

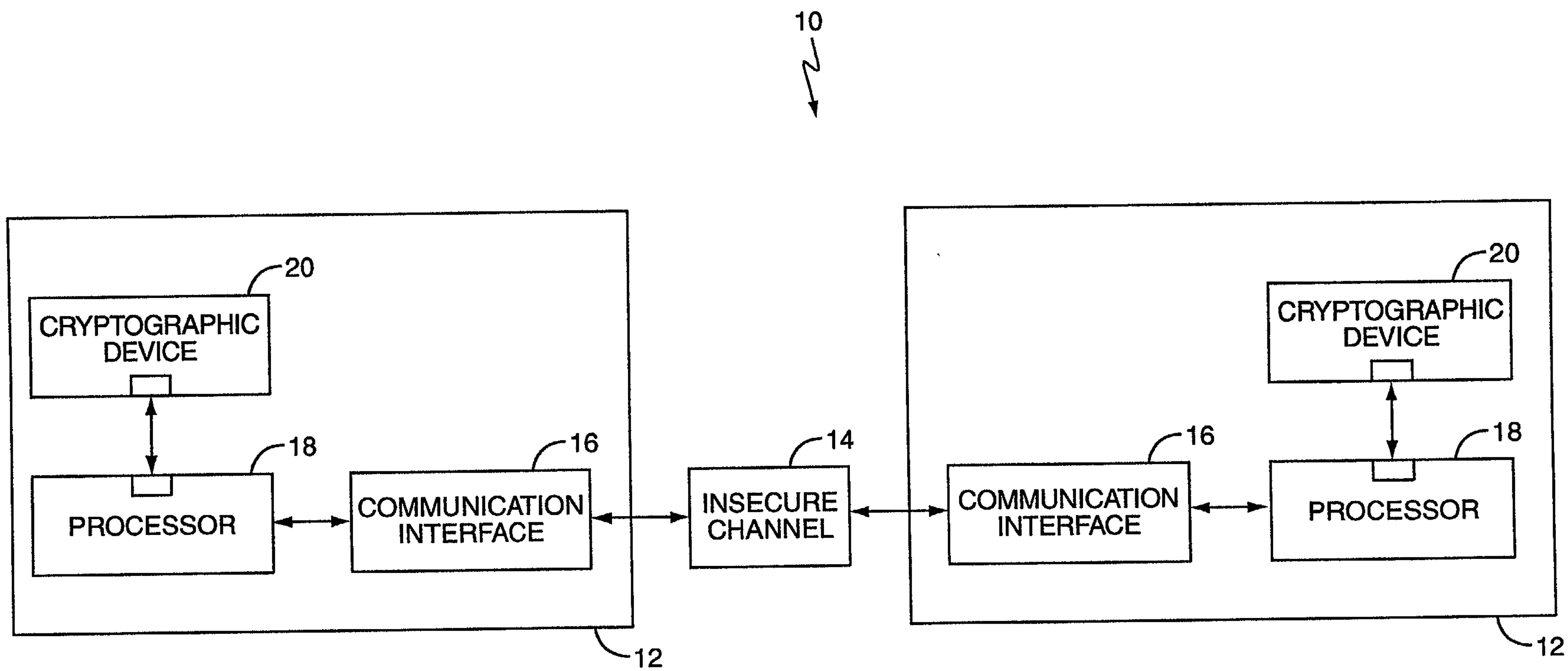

10
CRYPTOGRAPHIC DEVICE
20
PROCESSOR
18
COMMUNICATION INTERFACE
16
12
INSECURE CHANNEL
14
COMMUNICATION INTERFACE
16
CRYPTOGRAPHIC DEVICE
20
PROCESSOR
18
12

FIG. 1

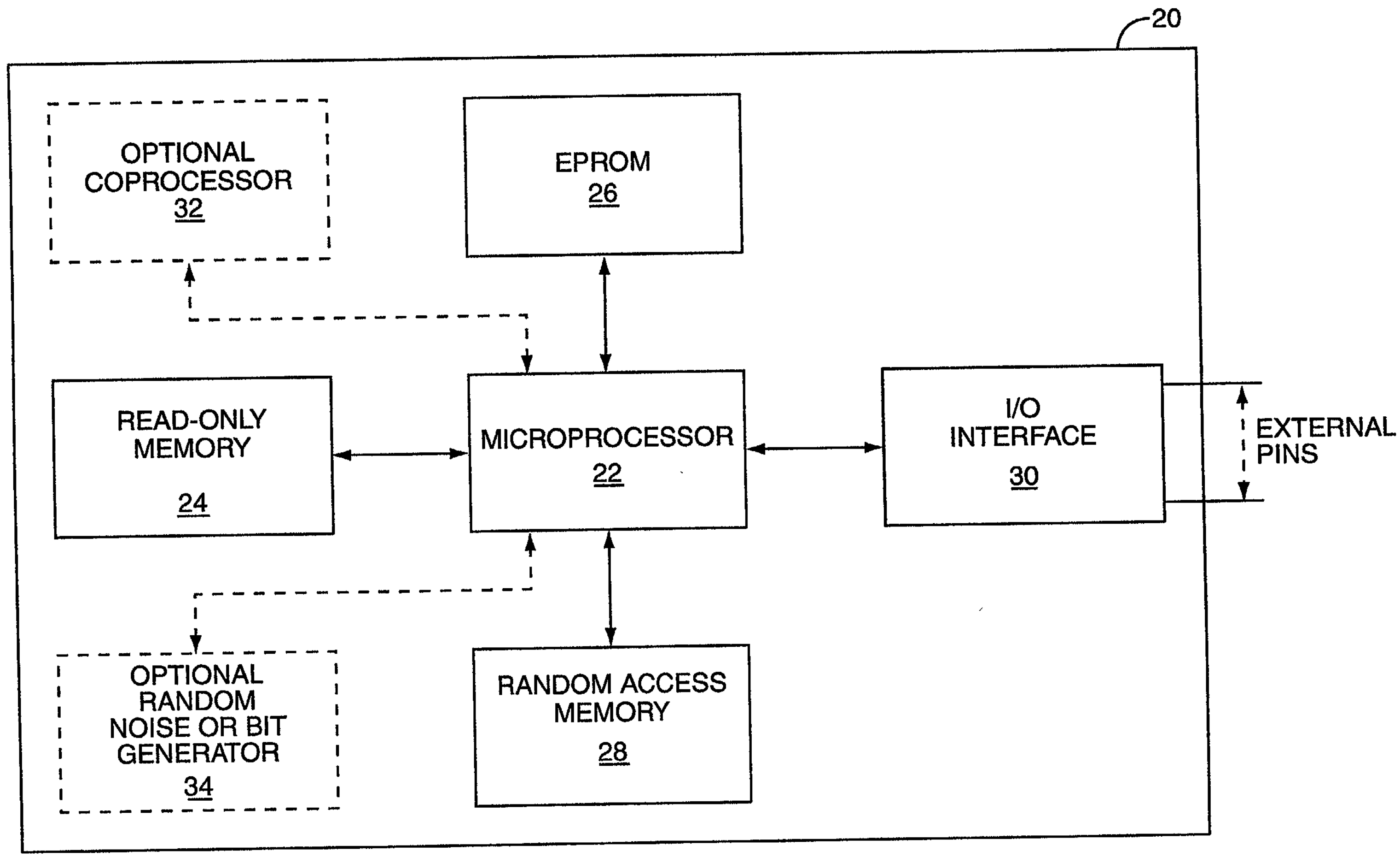
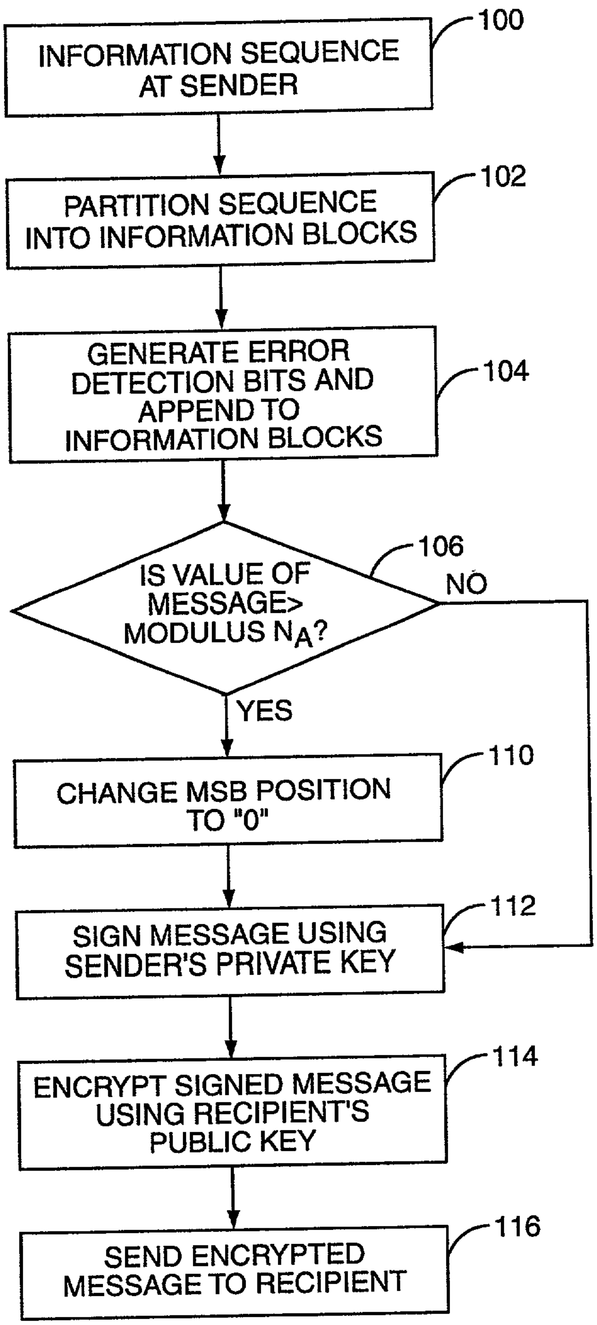

20
OPTIONAL
COPROCESSOR
32
EPROM
26
READ-ONLY
MEMORY
24
MICROPROCESSOR
22
I/O
INTERFACE
30
EXTERNAL
PINS
OPTIONAL
RANDOM
NOISE OR BIT
GENERATOR
34
RANDOM ACCESS
MEMORY
28

FIG. 2



INFORMATION SEQUENCE AT SENDER
100
PARTITION SEQUENCE INTO INFORMATION BLOCKS
102
GENERATE ERROR DETECTION BITS AND APPEND TO INFORMATION BLOCKS
104
IS VALUE OF MESSAGE> MODULUS NA?
106
NO
YES
CHANGE MSB POSITION TO "0"
110
SIGN MESSAGE USING SENDER'S PRIVATE KEY
112
ENCRYPT SIGNED MESSAGE USING RECIPIENT'S PUBLIC KEY
114
SEND ENCRYPTED MESSAGE TO RECIPIENT
116

FIG. 3

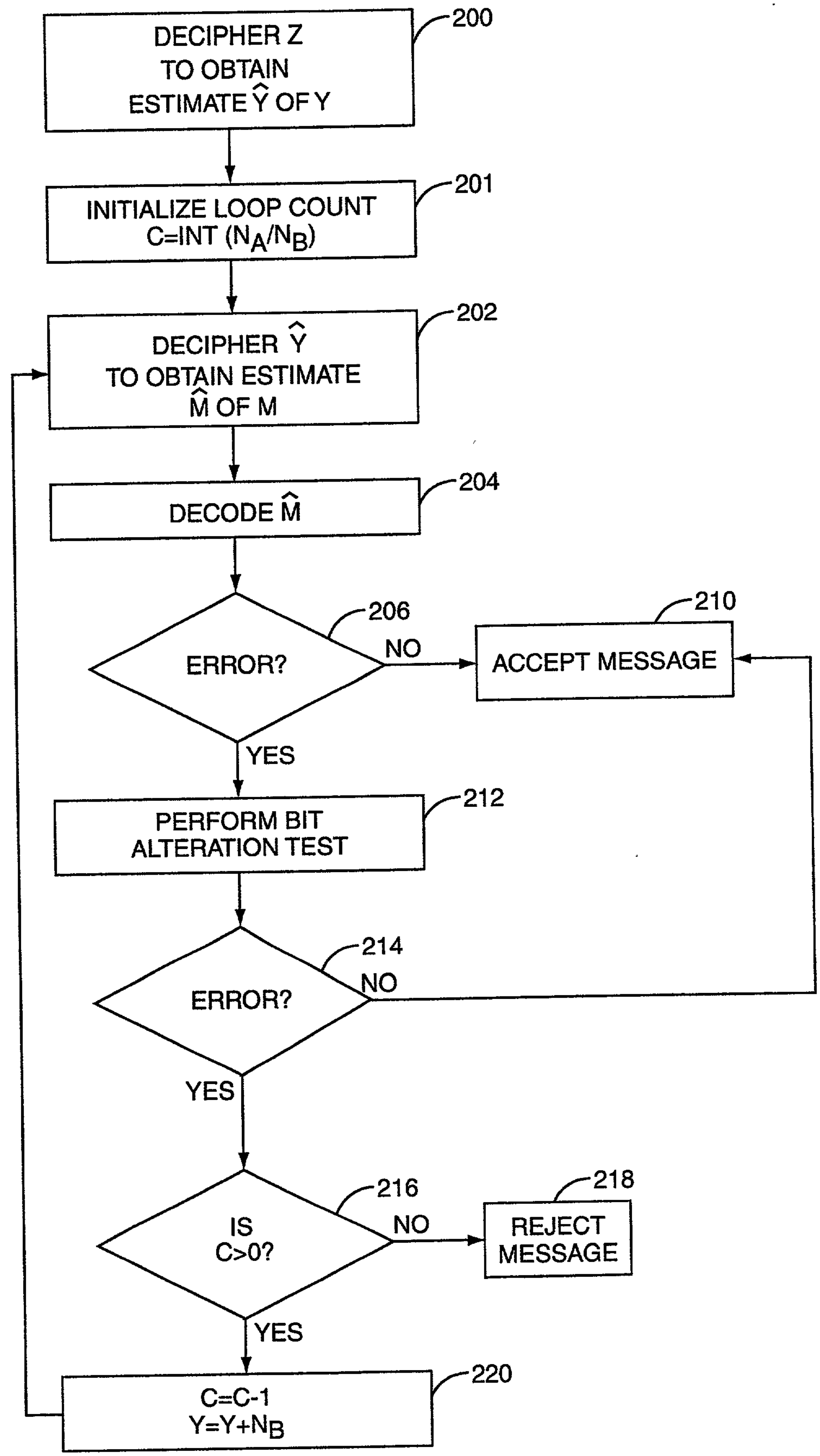

DECIPHER Z TO OBTAIN ESTIMATE $\hat{Y}$ OF Y
200
INITIALIZE LOOP COUNT C=INT (N_A/N_B)
201
DECIPHER $\hat{Y}$ TO OBTAIN ESTIMATE $\hat{M}$ OF M
202
DECODE $\hat{M}$
204
ERROR?
206
NO
ACCEPT MESSAGE
210
YES
PERFORM BIT ALTERATION TEST
212
ERROR?
214
NO
YES
IS C>0?
216
NO
REJECT MESSAGE
218
YES
C=C-1
Y=Y+N_B
220

FIG. 4

Declaration and Power of Attorney for Patent Application

As below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe that I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **CRYPTOGRAPHIC METHOD AND SYSTEM FOR DOUBLE ENCRYPTION OF MESSAGES**, the specification of which

[X] is attached hereto.

(Check one)

[ ] was filed on ____________ as
Application Serial Number ____________
and was amended on ____________.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to me which is material to patentability (as defined in C.F.R. §1.56) in connection with the examination of this application.

I hereby claim foreign benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
NONE (Number)	(Country)	(Day/Month/Year Filed)	[ ] YES	[ ] NO
(Number)	(Country)	(Day/Month/Year Filed)	[ ] YES	[ ] NO
(Number)	(Country)	(Day/Month/Year Filed)	[ ] YES	[ ] NO

Attorney Docket Number
P-4015.717/P11735(US1)-RMOT

Declaration and Power of Attorney for Patent Application

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing Date)	(Status: Patented/Pending/Abandoned)
NONE		

Power of Attorney: As a named inventor, I hereby appoint the following agents/attorneys to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

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Declaration and Power of Attorney for Patent Application

And I also hereby appoint the Attorneys and Patent Agents of **Coats & Bennett, P.L.L.C.**, as identified by **Customer Number 24112** in the records of the United States Patent and Trademark Office and as updated from time to time, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

24112
PATENT TRADEMARK OFFICE

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Direct Calls to:	David E. Bennett

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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